EFFECT OF EXHAUST GAS RECIRCULATION TO PERFORMANCE AND EMISSIONS OF DIESEL ENGINE

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Direct injection (DI) diesel engine is well design today as a main power train solution for trucks and others relevant heavy duty vehicles. However, at the same time emission legislation, mainly for oxides of nitrogens (NOx) and particulate matter (PM) becomes more obvious, reducing their limit to extremely low values. One efficient method to control NOx in order to achieve the future emission limit are the rather high exhaust gas recirculation (EGR) rates accompanied by increased boost pressure to avoid the negative impact on soot emissions. EGR is one of the most effective means of reducing NOx emissions from compression ignition (CI) engines and is widely used in order to meet the emission standards. In the present work, experimental investigation has been carried out to make an analysis the NOx reduction characteristics and the effect to the engine performance by using exhaust gas recirculation between two different fueled engine using biodiesel (palm oil methyl ester B5) and light diesel. This experiment was carried out using a four-cylinder DI diesel engine Mitsubishi 4D68. The purpose of this experiment was conducted is to know the effect of EGR on diesel engine performance and the quantity of NOx emissions in diesel engine's exhaust. The performance of the diesel engine and the quantity of NOx emissions in exhaust gas with using EGR in this experiment will be compared with the performance of the engine and the quantity of NOx emissions in the exhaust gas which not using EGR during the experiment. The results obtained by experiments showing that the EGR has caused the engine performance decreased as compared with no use of EGR. EGR is the best solution for reduced the production of NOx in the exhaust.

ABSTRAK

Pada zaman ini enjin diesel yang menggunakan sistem minyak suntikan langsung telah dibina dengan sebaiknya dan telah menjadi salah satu nadi penggerak utama bagi lori dan kenderaan besar yang lain. Pada masa yang sama, undang-undang pembebasan pencemaran ke udara sekeliling telah diketatkan, terutamanya bagi gas nitrogen oksida (NO_x) dan bendasing seperti jelaga hitam dari ekzos kenderaan yang menggunakan enjin diesel, undang-undang telah ditetapkan supaya kuantiti pembebasan asap dan jelaga ini dikurangkan kepada tahap yang paling rendah. Oleh itu, salah satu cara yang paling berkesan untuk mengurangkan kuantiti pembebasan gas NO_x ini ialah dengan menggunakan sistem resikulasi gas ekzos (EGR) dan disertai dengan meningkatkan tekanan yang tinggi dalam enjin bagi mengelakkan kesan negatif dalam pembebasan jelaga. EGR adalah salah satu cara yang paling berkesan untuk mengurangkan pembebasan gas NO_x dari enjin diesel dan digunakan secara meluas dalam rangka memenuhi piawaian pembebasan gas ekzos enjin diesel. Bagi membuktikan kenyataan ini, satu eksperimen telah dijalankan untuk menganalisis pengurangan pembebasan NO_x dalam asap ekzos dan kesan EGR ini terhadap prestasi enjin dengan menggunakan dua jenis minyak yang berbeza, iaitu minyak diesel biasa dan minyak biodiesel (minyak kelapa sawit B5). Eksperimen ini telah dijalankan dengan menggunakan enjin diesel mitsubishi 4D68. Tujuan eksperimen ini dijalankan ialah untuk mengatahui kesan penggunaan EGR pada prestasi enjin diesel dan kuantiti pembebasan gas NO_x dalam asap ekzos enjin diesel. Prestasi enjin diesel dan kuantiti pengeluaran gas NO_x yang menggunakan EGR dalam eksperimen ini akan dibandingkan dengan prestasi enjin dan kuantiti pengeluaran gas NO_x yang tidak menggunakan EGR semasa eksperimen dijalankan. Keputusan yang diperolehi berdasarkan eksperimen menunjukkan bahawa EGR telah menyebabkan prestasi enjin menurun berbanding dengan eksperimen yang tanpa menggunakan EGR. Namun begitu EGR adalah jalan penyelesaian terbaik untuk mengurangkan pengeluaran NOx dalam asap ekzos.

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LIST OF SYMBOLS

τ	Torque
π	pi
$\dot{w}$	Power
$\emptyset$	Equivalent Ratio

LIST OF ABBREVIATION

BDC	Bottom Dead Center
CI	Compression Ignition
CO_2	Carbon dioxides
DI	Direct Injection
EGR	Exhaust gar recirculation
HC	Hydrocarbon
NOx	Nitrogen oxides
O_2	Oxygen
PM	Particulate matter
r_c	Compression ratio
TDC	Top Dead Center

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays, people have come with new discovered source of fuel for the diesel engine named biodiesel. Biodiesel is an alternative choice of fuel to replace the crude oil from the industry. Biodiesel fuel offers a potential reduction of carbon dioxides (CO_2) and hydrocarbon (HC) emissions due to its higher content of oxygen (O_2). Many studies of biodiesel engine have found that exhaust from biodiesel fuel has higher nitrogen oxide (NO_x) emissions while HC and lower particulate matter (PM) than conventional diesel fuel (Yoshimoto, Onodera et al., 1999)

EGR is used to solve the problem of excessive NO_x emission from the biodiesel exhaust (Santoh, Zhang et al., 1997). EGR is operated by re-circulating the gas produced by the diesel engine exhaust back to the engine cylinder, so that the exhaust gas which is re-circulating replaces some of the excess O_2 in the pre-combustion mixture. At higher temperature which is about 1371^0C, the formation of NO_x will be faster. Chemical gases are formed from the chemical reaction between nitrogen (N_2) and O_2 in the combustion chamber. When these gases react with HC with the presence of sunlight, a black haze will appear in the skies known as smog. The EGR reduces the amount of NO_x in the exhaust gas emission by re-circulating it into the intake manifold where it mixes with air-fuel-ratio charge. The result of the mixing of inlet air with re-circulated gas is that peak combustion temperature and pressure are reduced by diluting the mixture of air-fuel-ratio at these conditions.

Generally, EGR flow is divided into three conditions. Firstly is high EGR flow. High EGR flow is necessary during cruising and mid-range acceleration and it happens when the combustion temperature is very high. Secondly is low EGR flow which is necessary at low speed and light load condition. Lastly is no EGR in which this condition occurs when EGR operation could adversely affect engine operating efficiency or vehicle drivability, such as when engine is warmed up, idling, and when the throttle is wide open.

The operation of the EGR will affect the performance of the diesel engine. Theoretically, EGR system has to precisely match with the various EGR flows and to over ride flow under condition which would give the best performance to the engine. A precise combination of the amount of EGR into the intake manifold and the load change will give a good result to the engine performance. The engine performance will be reduced if the exhaust gas is too much metered into the intake manifold. While in the other hand, if too little EGR flow goes into the intake manifold, it will also give a negative effect in which the engine might suffer from knocking and thus end up not meeting strict emission standards.

The effectiveness of EGR to reduce the emission contained in the exhaust gas depends on the flow of EGR. When the flow is too slow, it will cause detonation and emissions failure for excessive NO_x, because EGR tends to reduce the vitality of the air fuel charge. Otherwise, when too much EGR, an excessive flow for driving condition will cause stumble, flat spot, hesitation, and surging. This problem happens because EGR dilutes the air-fuel charge. When the flow of EGR is too much compared to the engine demand, misfiring happens.

1.2 OBJECTIVES

To performed this experiment smoothly, several objective are aimed. The objectives of this experiment are:

i. To analyze the significance of exhaust gas recirculation (EGR) system in reducing nitrogen oxide in the exhaust gas emissions
ii. To study the effects of the EGR system towards the performance of the engine
iii. To compare the effects of using biodiesel and diesel fuel to the performance and emissions of a diesel engine.

1.3 SCOPES OF THE PROJECT

The scope of this experiment covers the aspects as stated below:

i. Install the engine with sensors such as thermocouples and pressure transducer.
ii. Calibrate the data acquisition system for data correction.
iii. Test the engine performance and gas emissions with and without EGR.

1.4 PROBLEMS STATEMENT

The problem statements of this experiment are shown below:

i. The advantages of using EGR in solving the problem to reduce the amount of nitrogen oxide in exhaust gas emission and its effects to the performance and emissions of the diesel engine.
ii. The difference between using diesel fuel and biodiesel fuel in its effects to the amount of nitrogen oxide emissions in the exhaust gas.
iii. The difference between the diesel engine performances when using diesel fuel and biodiesel fuel.

1.5 FLOW CHART FOR THIS PROJECT

This flow chart is about the flow of the experiment which was carried out to test the effect of the EGR towards the performance and emissions of a diesel engine.

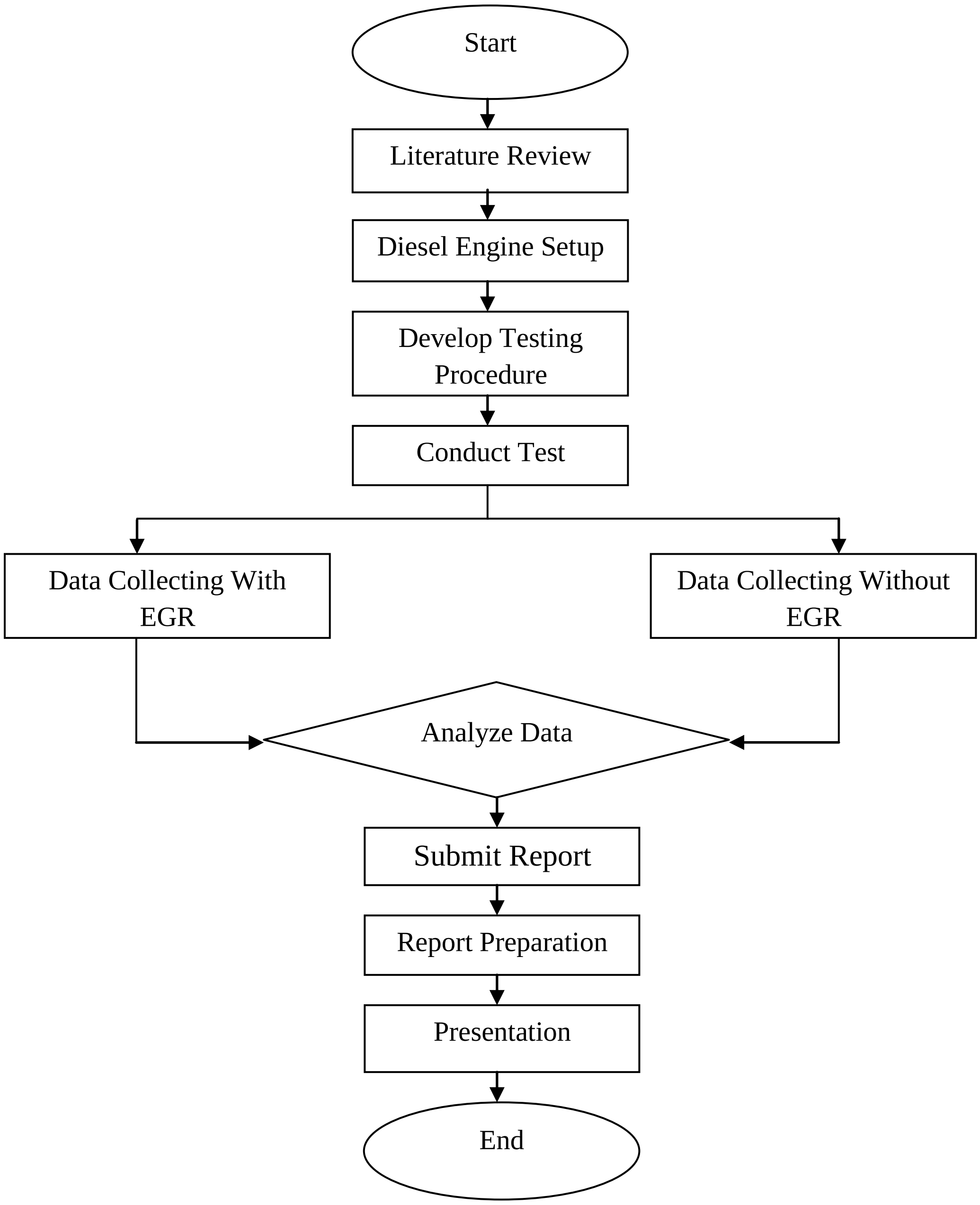

Figure 1.1 : Flow Chart for his project

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter consists of reviews about the related content or knowledge with regards to the effect of EGR towards the performance and emissions of a diesel engine.

2.2 DIESEL ENGINE

Diesel engine is like a gasoline engine, it is an internal combustion engine that converts chemical energy in fuel to mechanical energy which makes the piston moves up and down in the cylinders. To change the motion of the piston in the engine from linear motion to rotational motion, the pistons are connected to the crankshaft. This motion is needed to drive the vehicle’s wheel. The primary difference between the diesel engine and the gasoline engine is in the way the explosion in the cylinder occurs. In diesel engine operation, the fuel ignites on its own. Air heats up when it is compressed. Therefore, the spark plug and carburetor are replaced by a fuel injector in diesel engine. When the piston approaches the Top Dead Center (TDC), the fuel injection process in diesel engines will start and this process will continue during the first part of the power stroke. Therefore, the combustion process will happen over a long interval. The combustion process in the ideal diesel cycle is approximated as a constant-pressure heat addition process.

Process 1-2 is an isentropic compression, while 3-4 is an isentropic expansion and 4-1 is a constant heat-volume rejection (Cengel and Boles, 2007). Hence diesel engine is also known as compression ignition engine, it also has a high thermal efficiency because of its high compression ratio and fuel lean operation. To achieve the auto-ignition, high compression ratio is required as it will produce high temperature, so that the high expansion ratio will make the engine discharge less thermal energy in the exhaust. To complete and compensate the combustion for homogeneity in the fuel distribution, the extra oxygen (O_2) is necessary to facilitate it. However, locally stoichiometric air will cause the high flame temperatures predominate, so in such heterogeneous combustion process the fuel ratios will prevail (BormanGL and GaglandKW, 1998)

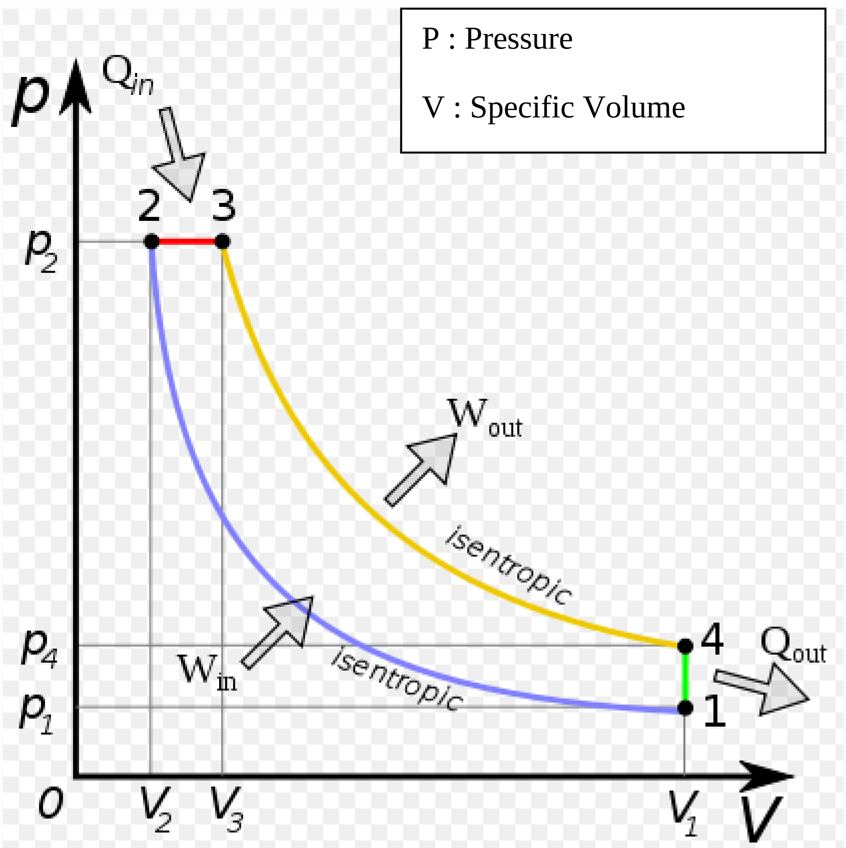

Figure 2.1 : Ideal p-v diagram for diesel cycle

Source : From the thermodynamics text book – an engineering approach sixth edition (SI units), Yunus A. Cengel, 2007

2.2.1 Compression Ratio

Compression ratio (r_c) is important in diesel engine. It is because, when air is compressed, the collision between molecules in cylinder will produce heat that ignites the diesel fuel. Compression ratio is the parameter to measure how much the air is compressed.

$$\text{Compression Ratio} = \text{swept volume} + \frac{\text{clearance volume}}{\text{sweapt volume}} \quad (2.1)$$

- Swept Volume – the volume of the cylinder transverse by the piston travel from top dead center (TDC) to bottom dead center (BDC).
- Clearance Volume – combustion chamber volume.

The diesel engine needs a very minimum compression ratio at about 15:1. This is at the cold starting condition. When the compression ratio is higher, for example 16 or 17:1, the benefits are that the starting becomes easier and less exhaust smoke is produced. A compressor in the mode of turbocharger and supercharger will raise the effectiveness of the compression ratio (Dampsey, 2008).

2.2.2 Induction

In CI engine, the air is compressed first and only then the fuel will be admitted. The injector will be opened to inject the fuel when the piston is at the TDC. The advantage of compressing air rather than the mixture of oil and air to diesel engine is that it can increase the thermal efficiency of the engines. The compression ignition engine dispenses with the throttle plate. This plate’s function is to ensure that the amount of air entering the cylinder at all speed is same. At high speed or under heavy load, the additional fuel supplied drops to a ratio about 20:1. So without this plate, the diesel engine will be able to breathe easily at low speed. For example, a truck can idle for long periods without consuming appreciable fuel.

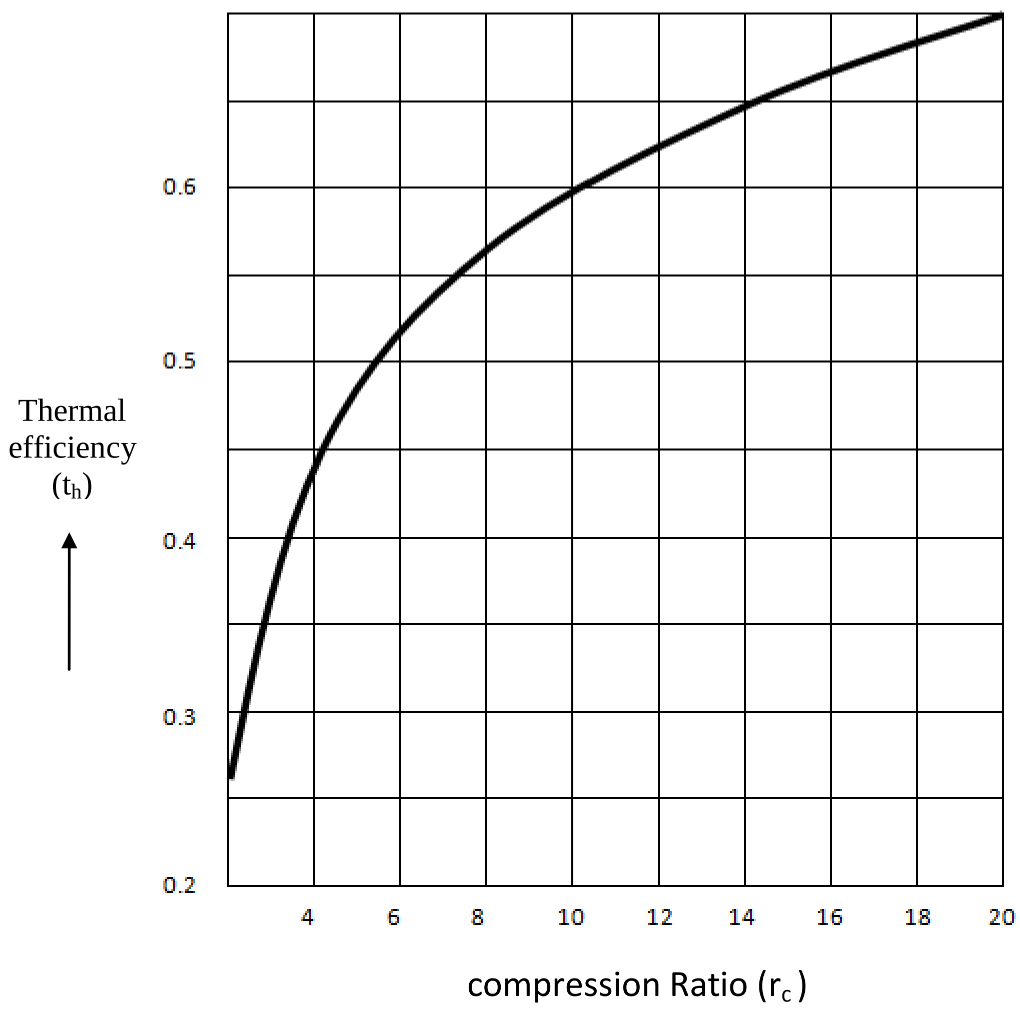

Figure 2.2 : Standard graph of relationship between diesel compression ratio and thermal efficiency.

Source : From the book of Trouble shooting and repairing diesel engine, Dampsey, 2008

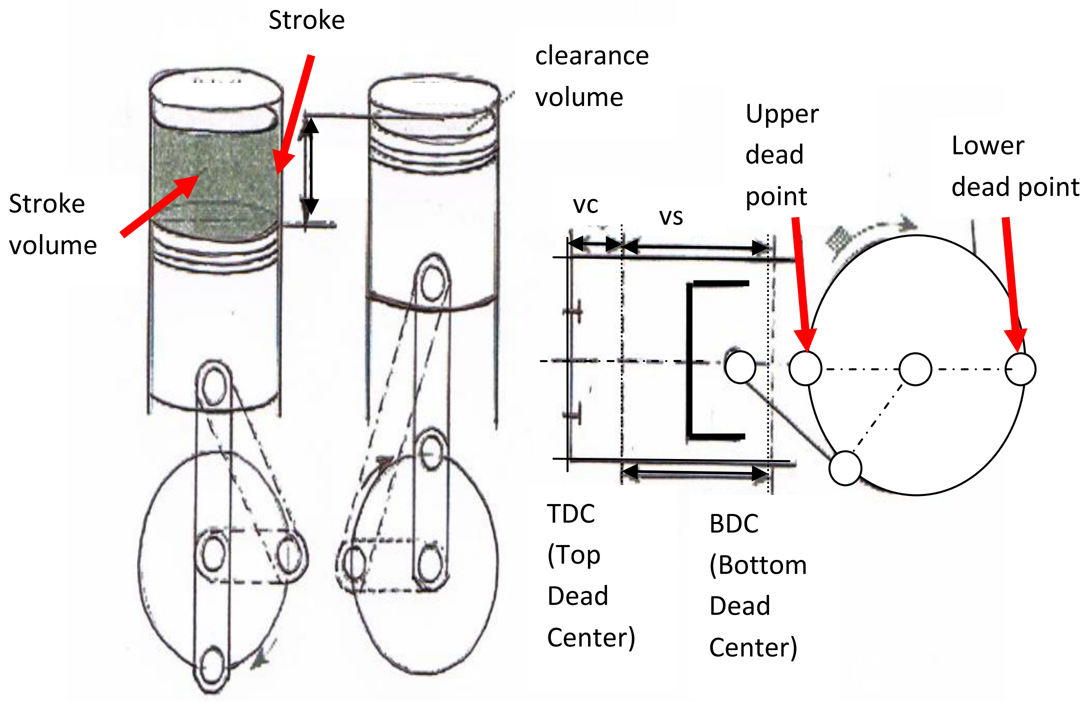

Figure 2.3 : Schematic diagram of diesel engine compression ratio

Source : From the book of Trouble shooting and repairing diesel engine, Dampsey, 2008

2.2.3 Ignition and Combustion

The ignition in diesel engines happens rapidly with accumulated fuel burns corresponding to the temperature and pressure that increase rapidly. At the time rapid combustion happens, the injector is still receiving the fuel and thus a period of controlled combustion follows. The greater the ignition lag, the more violent the combustion as well as greater resulting noise, vibration and harshness (Dampsey, 2008). During the initial starting, at the time where the engine in the cold condition, the ignition lag becomes very bad. The will produce noise, white smoke, and rough combustion as known as ‘diesel detonation’. This phenomenon will disappear when the engine condition is warm.

2.2.4 Two Stroke and Four Stroke Cycle

The operation of a four stroke-cycle of an engine is as shown in the Figure 2.4. At the first cycle, intake valve is opened and air is allowed to enter into the cylinder. Then the intake valve is closed at the second cycle as the piston at the BDC moves up to the TDC thus compressing the volume of air inside the cylinder. At the high compression and temperature, the fuel is injected for ignition. When the fuel is ignited, it drives the piston down as known as expansion cycle and this is third cycle. Then the last cycle, the exhaust valve opened and the piston rises again to reject the spent mixture of gases and fuel. This cycle called the exhaust stroke completes the cycle (Dampsey, 2008). However for the two cycle engine, the intake stroke and the compression stroke are combined to be one cycle. The third and fourth cycle, expansion stroke and exhaust stroke are also combined to become one cycle.

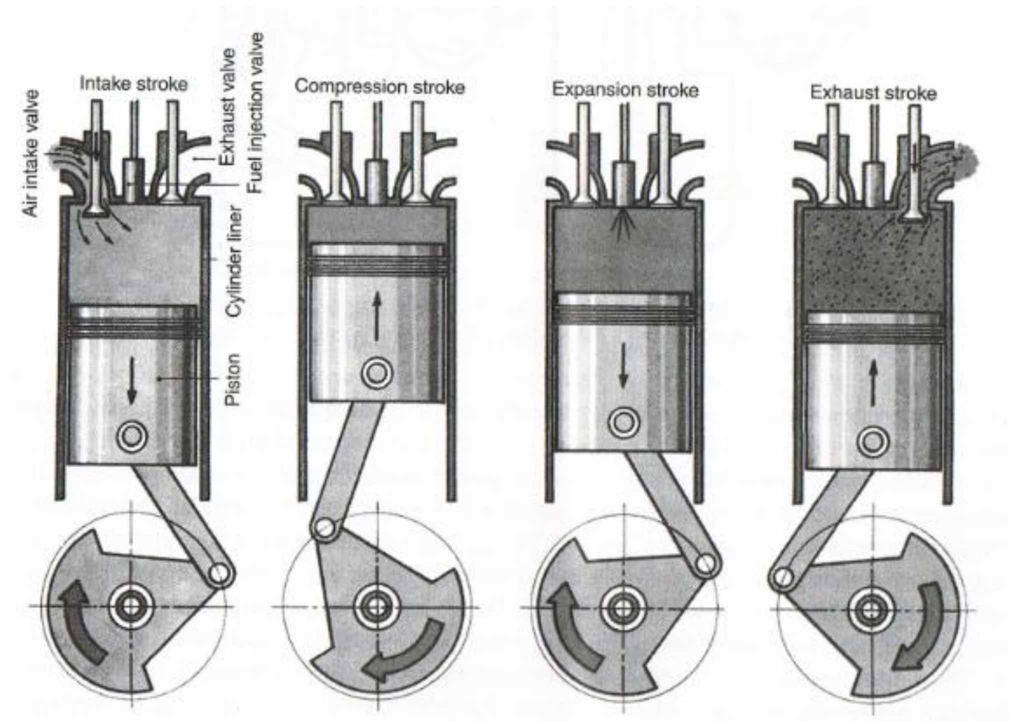

Figure 2.4 : Schematic diagram of Four stroke-cycle

Source : From the book of Trouble shooting and repairing diesel engine, Dampsey, 2008